CHAPTER 1
INTRODUCTION

The U.S. Department of the Interior (DOI), U.S. Department of Agriculture (USDA), and Coeur d'Alene Tribe (collectively, the Trustees) have undertaken a natural resource damage assessment (NRDA) to assess damages resulting from releases of hazardous substances from mining and mineral processing operations in the Coeur d'Alene River basin, Idaho. Section 107 of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) [42 U.S.C. § 9607], Section 311 of the Federal Water Pollution Control Act (CWA) [33 U.S.C. § 1321], and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) [40 C.F.R. Part 300] provide authority to the Trustees to seek such damages.

This report presents the results of the injury determination studies, as well as an initial quantification of the injuries to natural resources.

The DOI has promulgated regulations for conducting NRDAs [43 CFR Part 11]. The Trustees have relied on these regulations in assessing the natural resource damages. The application of these regulations is not mandatory, and the Trustees have the option of diverging from them as appropriate. However, assessments performed in compliance with these regulations have the force and effect of a rebuttable presumption in any administrative or judicial proceeding under CERCLA [42 U.S.C. § 9607 (f)(2)(C)].

This report of injury assessment and injury determination follows the 1991 "Preassessment Screen of Natural Resource Damages in the Coeur d'Alene Watershed Environment from Mining and Related Activities Taking Place in and about the Bunker Hill Superfund Site," the Phase 1 (Injury Determination) Assessment Plan (Ridolfi, 1993), and the Phase II (Injury Quantification and Damage Determination) Assessment Plan of 1996 (U.S. Fish and Wildlife Service, U.S. Department of the Interior and Coeur d'Alene Tribe, 1996).

In subsequent reports, the results of the damage determination and restoration planning phases of the NRDA will be documented. Figure 1-1 presents an overview of this regulatory process.

1.1 INJURY ASSESSMENT

The purpose of the injury determination phase of an NRDA is to determine whether natural resources of the Coeur d'Alene River basin have been injured as a result of releases of hazardous substances [43 CFR § 11.61], and to identify the environmental pathways by which injured resources have been exposed to hazardous substances [43 CFR § 11.63]. DOI regulations define "injury" as a:

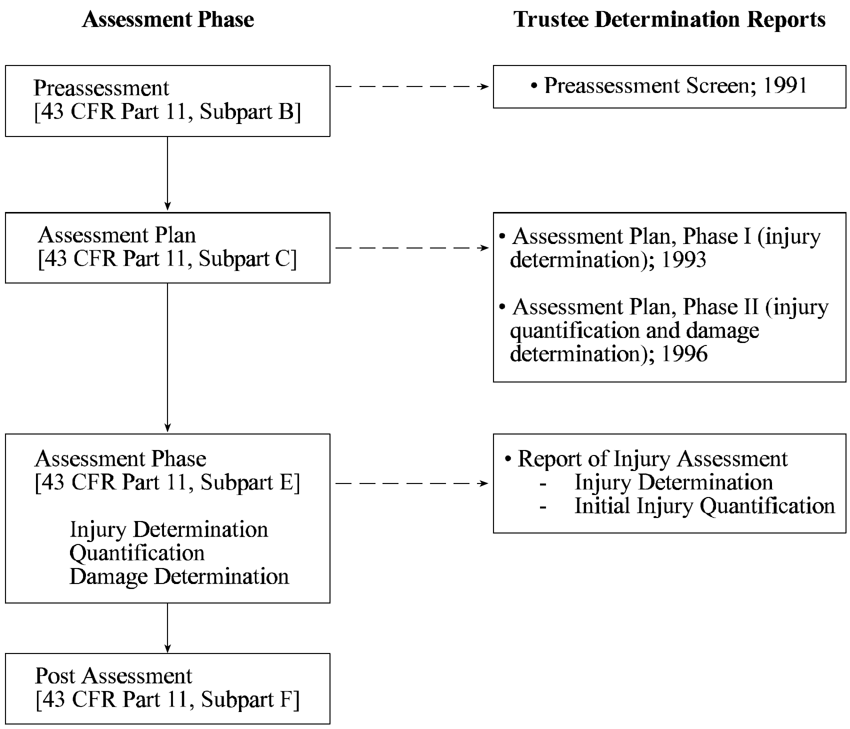

Figure 1-1. Overview of regulatory process and relationship to release of key NRDA determination reports. See 43 CFR § 11.13.

> . . . measurable adverse change, either long- or short-term, in the chemical or physical quality or the viability of a natural resource resulting either directly or indirectly from exposure to a release of a hazardous substance, or exposure to a product of reactions resulting from the release of a hazardous substance [43 CFR § 11.14 (v)].

The overall injury assessment process includes the following phases:

1. **Injury Definition.** In the injury definition phase, adverse effects to natural resources that have resulted from releases of hazardous substances, and that meet the definitions of injury in 43 CFR § 11.62, as well as other relevant injury categories, are determined.

2. **Pathway Determination.** In the pathway determination phase, exposure pathways for transport of hazardous substances to injured natural resources are identified [43 CFR § 11.63]. The pathway determination phase connects the injury to the releases of hazardous substances.

These first two steps constitute the "injury determination" phase of the injury assessment and are the focus of this report.

The final component of the injury assessment phase is "injury quantification," in which the injuries that have been determined are quantified in terms of changes from "baseline conditions" [43 CFR § 11.70 (a)]. Specific steps in the quantification phase included measuring the extent of injury relative to baseline conditions[1] and quantifying the spatial and temporal extent of injury [43 CFR § 11.71 (b)]. This report presents an initial quantification of injury. However, the purpose of injury quantification is "for use in determining the appropriate amount of compensation" in an NRDA [43 CFR § 11.70 (b)]. Because the Trustees' claim for compensation (i.e., damages) will be based on calculation of restoration costs and must include consideration and estimation of losses residual to any remedial or response actions undertaken in the Coeur d'Alene River basin by the U.S. Environmental Protection Agency or other response agencies, final injury quantification cannot be performed until remedial and response actions are determined and the Trustees prepare a restoration plan. Thus, the initial quantification of injury presented in this report is subject to change.

1.2 CONTENTS OF THE REPORT OF INJURY ASSESSMENT

This report of injury assessment describes the results of the injury determination studies and the initial quantification of those injuries. Sources of hazardous substances released into the Coeur d'Alene River basin environment are identified and described, and environmental pathways by which hazardous substances have been transported throughout the Coeur d'Alene River basin, and by which natural resources have come to be exposed to released hazardous substances, are identified and described. Injuries to natural resources are defined, and information and data used in the determination of injuries to various natural resources are presented.

Natural resources include the land, fish, wildlife, biota, air, and water belonging to, managed, held in trust, appertaining to, or otherwise controlled by the United States, any state or local government, or any Indian tribe [43 CFR § 11.14 (z)]. The natural resources addressed in this report include:

- surface water
- sediments
- wildlife
- fish

1. Baseline conditions are the conditions that "would have existed at the assessment area had the . . . release of the hazardous substance . . . not occurred" [43 CFR § 11.14 (e)] and are the conditions to which injured natural resources should be restored [43 CFR § 11.14 (ll)].

- aquatic invertebrates
- riparian soils and vegetation.

The area assessed for natural resource injuries includes the South Fork Coeur d'Alene River basin, tributary drainages to the South Fork Coeur d'Alene River in which mining and milling has occurred, the mainstem Coeur d'Alene River and lateral lakes and wetlands that border the lower river, and Coeur d'Alene Lake from the mouth of the Coeur d'Alene River at Harrison to the lake's outlet at the Spokane River.

Finally, an initial quantification of the injuries determined to have occurred is presented. The quantification includes an analysis of baseline conditions, quantification of the extent of injury, and an initial determination of resource recoverability without other response or restoration actions.

1.3 DESCRIPTION OF THE COEUR D'ALENE RIVER BASIN AND NATURAL RESOURCES ASSESSED

The Coeur d'Alene River originates near the Idaho-Montana border and flows west, draining approximately 3,810 km^2 of the western slope of the Bitterroot Mountains (Beckwith et al., 1997) (Figure 1-2). The North and South Forks of the Coeur d'Alene River are rocky, high-gradient streams in narrow valleys confined by steep hillsides. The North and South Forks converge to form the mainstem Coeur d'Alene River. The mainstem Coeur d'Alene River is a fine substrate, low gradient, meandering river in a broad valley. In the broad valley, 12 shallow lateral lakes and thousands of acres of wetlands are hydraulically connected to the mainstem Coeur d'Alene River. The mainstem Coeur d'Alene River flows into Coeur d'Alene Lake near Harrison. Coeur d'Alene Lake is a large natural lake fed mainly by the Coeur d'Alene River and the St. Joe River. Coeur d'Alene Lake discharges to the Spokane River at the north end of the lake.

In the headwater and tributary areas, predominant land uses include mining, mineral processing, forestry, and urban and residential land use. The towns of Mullan and Wallace, a discontinued railroad, a state highway, and Interstate 90 parallel border the South Fork Coeur d'Alene River. In the narrow tributary canyons, small communities, dispersed residences, and roads border the streams.

The floodplain of the South Fork Coeur d'Alene River from Wallace to Pinehurst is characterized by urban and industrial land uses. These include a discontinued railroad, a state highway, the interstate, and the towns of Osburn, Kellogg, Smelterville, and Pinehurst. The river has been channelized along much of this reach by the railroad and roads.

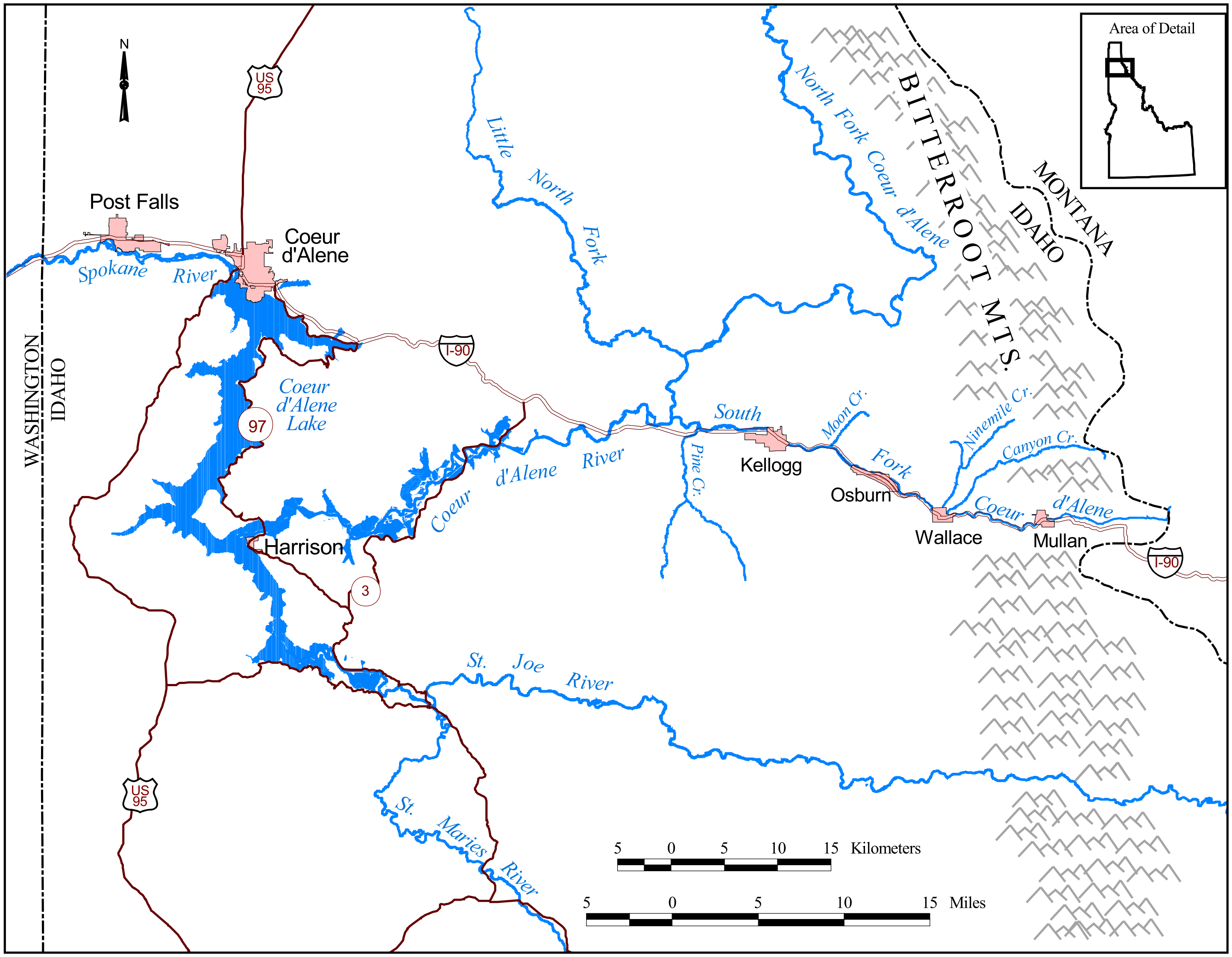

Figure 1-2. Map of Coeur d'Alene River basin.

Land use along the lower Coeur d'Alene River, its floodplain, and the lateral lakes area is predominantly agricultural, residential, and recreational. The discontinued railroad runs through the floodplain, and associated berming has modified water flow between several of the lakes and the river. Agricultural use is largely hay and pasture.

1.3.1 General Geology and Mineralogy of the Coeur d'Alene District

The geology of the Coeur d'Alene District is dominated by partially metamorphosed sedimentary rocks of late Precambrian age belonging to the Belt Supergroup. These rocks are predominantly argillite (sedimentary rock composed of silt and/or clay) and quartzite, with lesser amounts of disseminated dolomite and limestone in the upper part of the section. The Belt Supergroup rocks were originally deposited in a geosyncline and cover a large area, including north and central Idaho, western Montana, southeastern British Columbia, and Alberta. Belt rocks in the Coeur d'Alene area are the host rock for the ore deposits that have been mined in the basin. Igneous monzonite intrusions (a granite-like rock) of Cretaceous age cut through the Belt rocks north of the South Forth Coeur d'Alene River in the Ninemile/Canyon Creek area (known as the "Gem Stocks") and the area to the west of Ninemile Creek ("Dago Stocks") (Hobbs et al., 1965; Gott and Cathrall, 1980). Detailed geologic maps of the district are shown in Chapter 10.

The Belt rocks in the Coeur d'Alene District are cut by a complex series of faults, the largest of which is the 100-mile-long Osburn fault. This fault follows the valleys of the South Fork Coeur d'Alene River in Idaho and the St. Regis River and parts of the Clark Fork River in Montana (Hobbs et al., 1965). The Osburn fault is part of an extensive fault called the Lewis and Clark line, which extends for approximately 500 miles from south-central Montana to Spokane, Washington (Hobbs et al., 1965). The Osburn fault is a strike-slip fault with approximately 16 miles of lateral (roughly east-west) displacement. It is widely believed that the ore bodies were originally formed in this "structural knot" and then separated and moved along the Osburn fault. For example, the two main areas of mineralization — Kellogg south of the fault and the Mullan-Burke area north of the fault — are separated by approximately 16 miles.

The ore deposits of the Coeur d'Alene District occur predominantly as high grade veins consisting of variable amounts of sphalerite (zinc sulfide, ZnS), galena (lead sulfide, PbS) and argentiferous tetrahedrite (an arsenic-antimony sulfide with varying proportions of copper, iron, zinc and/or silver) ($(Cu,Fe,Zn,Ag)_{12}(Sb,As)_4S_{13}$) (White, 1998). The non-ore minerals in the veins consist mostly of quartz (SiO_2) or siderite (ferrous iron carbonate, $FeCO_3$).

1.3.2 Valley Morphology

Valley shape in the Coeur d'Alene River basin can be grouped as V-shaped canyons, U-shaped canyons, and broad basins. The South Fork Coeur d'Alene River upstream of Wallace is confined by a V-shaped canyon. Canyon, Ninemile, Moon, Lake, Big, and upper Pine creeks are also V-shaped canyons. These reaches have high gradients, are largely incised, and are channelized in places, either naturally by bedrock, or by roads, railroads, and mining-related disturbances.

Downstream of Wallace, the South Fork flows through a U-shaped canyon. Stream and valley gradients in these areas decrease relative to gradients upstream. The valley bottom and floodplains widen, although topographic features impose localized channel constriction. Near Osburn and from Kellogg to Smelterville, the canyon widens further. Within these depositional reaches, the gradient is lower and the floodplain is substantially wider. These areas are highly modified by industrial, urban, and residential land use. The lower North Fork of the Coeur d'Alene River (the North Fork) and Little North Fork, lower Canyon Creek, lower Big Creek, and lower Pine Creek also open into U-shaped canyons.

Downstream of Enaville and the confluence with the North Fork, the Coeur d'Alene River is deeper, slower moving, and the sinuosity increases. The valley opens into a broad alluvial basin, with the floodplain width exceeding one mile in places. The river is bordered by 12 lateral lakes ranging in size from less than 85 acres to over 600 acres (Ridolfi, 1993). Thousands of acres of wetlands are associated with the lateral lakes.

The Coeur d'Alene River flows into Coeur d'Alene Lake near Harrison, ID. Coeur d'Alene Lake is a large natural lake fed mainly by the Coeur d'Alene River and the St. Joe River. The drainage area of Coeur d'Alene Lake is approximately 3,440 square miles (Woods and Beckwith, 1997). Coeur d'Alene Lake discharges to the Spokane River at the north end of the lake. Lake elevation is controlled by the Post Falls Dam on the Spokane River near the Idaho-Washington state line. The normal full pool elevation for the Coeur d'Alene Lake is 2,128 feet msl (WWPC, 1996). At this elevation, the lake's surface area is approximately 50 square miles, mean depth is about 72 feet, and maximum depth is about 209 feet (CLCC, 1996). Operation of the Post Falls Dam also affects the surface water elevation and hydraulics of the lower segments of the mainstem Coeur d'Alene River and lateral lakes.

1.3.3 Ecological Communities

Terrestrial and Wetland Communities

In the high-gradient, headwater, V-shaped canyons, and in the medium gradient, U-shaped canyons, terrestrial communities include riparian and upland communities. Where local gradient allows, wetland communities may also occur (or may have been present in the past). Riparian communities in the narrow V-shaped canyons (based on sampling conducted in reference areas for the riparian resources injury assessment, see Chapter 9) are dominated by thinleaf alder (*Alnus incana*), snowberry (*Symphoricarpos albus*), bush honeysuckle (*Lonicera involucrata*), and goldenrod (*Solidago* spp.) in the shrub layer, and wild ginger (*Asarum caudatum*), aster (*Aster modestus*), lady fern (*Athyrium filix-femina*), red top bentgrass (*Agrostis stolonifera*), violet (*Viola glabella*), bluebell (*Mertensia paniculata*), fescues (*Festuca* spp.), and oxeye daisy (*Chrysanthemum leucanthemum*) in the herbaceous layer (Table 1-1). Black cottonwood (*Populus trichocarpa*) and conifers such as grand fir (*Abies grandis*), white pine (*Pinus monticola*), and, in higher elevations, western hemlock (*Tsuga heterophylla*) may also be present in the riparian zone.

In U-shaped, open riparian reference areas where the stream meanders more, willow (*Salix* spp.) communities develop on point bars. Black cottonwood, Rocky Mountain maple (*Acer glabrum*), grand fir, western hemlock, and western red cedar (*Thuja plicata*) are typical canopy layer dominants (Table 1-2). Historically, the valley flats along the South Fork Coeur d'Alene River were dominated by western red cedar stands. Dominant shrub species in reference areas include willows, thinleaf alder, cascara (*Rhamnus purshiana*), ninebark (*Physocarpus malvaceous*), serviceberry (*Amelanchier alnifolia*), snowberry, red-osier dogwood (*Cornus stolonifera*), and mockorange (*Philadelphus lewisii*). Typical herbaceous layer dominants include mosses, bluebell, lady fern, redtop bentgrass, reed canarygrass (*Phalaris arundinacea*), sedges (*Carex* spp.), marsh cinquefoil (*Potentilla palustris*), and Solomon-seal (*Smilacina stellata*).

The structure and composition of upland plant communities are strongly influenced by the length of the growing season, moisture availability, and the seasonal distribution of moisture. Gross physical factors that control moisture availability and growing season length include elevation, slope, and aspect. High points near the headwaters of the South Fork Coeur d'Alene River (upstream of Mullan) and in the upstream reaches of Canyon and Ninemile creeks range from approximately 5,000 to 6,600 ft. Between Wallace and Kellogg, high points adjacent to the riparian corridor are generally within the 3,000 to 4,500 ft elevation range, and between Kellogg and Cataldo, 2,000 to 3,500 ft. South facing slopes are typically warmer and drier and support more xeric shrubland and grassland communities. North facing slopes tend to be heavily forested with conifers. Valley bottoms generally stay cooler than slopes with a southerly or westerly aspect, partially a result of diurnal temperature fluctuation and cold air drainage down valley. Additional orographic effects may produce cold-air pockets that result in localized vegetation response.

Table 1-1
Typical Dominant Vegetation Species in Coeur d'Alene River Reference Riparian Communities

Narrow V-Shaped Canyons			**Open U-Shaped Canyons**		
Herbaceous layer:	wild ginger	*Asarum caudatum*	Herbaceous layer:	bluebell	*Mertensia paniculata*
	aster	*Aster modestus*		lady fern	*Athyrium filix-femina*
	lady fern	*Athyrium filix-femina*		redtop bentgrass	*Agrostis stolonifera*
	red top bentgrass	*Agrostis stolonifera*		reed canarygrass	*Phalaris arundinacea*
	violet	*Viola glabella*		sedges	*Carex* spp.
	bluebell	*Mertensia paniculata*		marsh cinquefoil	*Potentilla palustris*
	fescues	*Festuca* spp.		Solomon-seal	*Smilacina stellata*
	oxeye daisy	*Chrysanthemum leucanthemum*		moss spp.	
Shrub layer:	thinleaf alder	*Alnus incana*	Shrub layer:	willows	*Salix* spp.
	snowberry	*Symphoricarpos albus*		thinleaf alder	*Alnus incana*
	bush honeysuckle	*Lonicera involucrata*		cascara	*Rhamnus purshiana*
	goldenrod	*Solidago* spp.		ninebark	*Physocarpus malvaceous*
				serviceberry	*Amelanchier alnifolia*
				snowberry	*Symphoricarpos albus*
				redosier dogwood	*Cornus stolonifera*
				mockorange	*Philadelphus lewisii*
Tree layer:	black cottonwood	*Populus trichocarpa*	Tree layer:	black cottonwood	*Populus trichocarpa*
	grand fir	*Abies grandis*		grand fir	*Abies grandis*
	white pine	*Pinus monticola*		western hemlock	*Tsuga heterophylla*
	western hemlock	*Tsuga heterophylla*		western red cedar	*Thuja plicata*
				Rocky Mountain maple	*Acer glabrum*

Table 1-2
Typical Dominant Upland Vegetation Species in the Coeur d'Alene River Basin

North, east facing slopes:	western hemlock	*Tsuga heterophylla*
	western red cedar	*Thuja plicata*
	western white pine	*Pinus monticola*
	western larch	*Larix occidentalis*
	lodgepole pine	*Pinus contorta*
South, west facing slopes:	Douglas fir	*Pseudotsuga menziesii*
	grand fir	*Abies grandis*
	Ponderosa pine	*Pinus ponderosa*
Dry south facing slopes:	redtop bentgrass	*Agrostis stolonifera*
	bluebunch wheatgrass	*Agropyron spicatum*
	pinegrass	*Calamagrostis rubescens*
	tufted hairgrass	*Deschampsia cespitosa*
	ceanothus	*Ceanothus velutinus*
	huckleberry	*Vaccinium membranaceum*
	serviceberry	*Amelanchier alnifolia*
	chokecherry	*Prunus virginiana*
	mountain ash	*Sorbus* spp.
	ninebark	*Physocarpus malvaceous*
	snowberry	*Symphoricarpos albus*
	wild rose	*Rosa* spp.

Upland forest communities characteristic of north and east facing slopes are often dominated by western hemlock and western red cedar, along with western white pine, western larch (*Larix occidentalis*), and lodgepole pine (*Pinus contorta*) (Table 1-2). On south and west facing slopes, Douglas fir (*Pseudotsuga menziesii*), grand fir, and Ponderosa pine (*Pinus ponderosa*) are typical dominants. On the dry south facing slopes, grasses such as redtop bentgrass, bluebunch wheatgrass (*Agropyron spicatum*), pinegrass (*Calamagrostis rubescens*), and tufted hairgrass (*Deschampsia cespitosa*) and the shrub species ceanothus (*Ceanothus velutinus*), huckleberry (*Vaccinium membranaceum*), serviceberry, chokecherry (*Prunus virginiana*), mountain ash (*Sorbus* spp.), ninebark, snowberry, and wild rose (*Rosa* spp.), among others, are common.

Along the lower Coeur d'Alene River and lateral lakes, and the bays of Coeur d'Alene Lake, community types include riparian, palustrine, and lacustrine communities. These community types are differentiated by the predominant vegetation species and, particularly, the moisture tolerance of the dominant vegetation species. Riparian communities are typically dominated by black cottonwoods and willows in the overstory, and Douglas spiraea (*Spiraea douglasii*), willows, and red-osier dogwood in the shrub layer. The herbaceous layer may be quite diverse, with no single species dominant, although typical species include redtop, reed canarygrass, and sedges.

Palustrine and lacustrine communities are the dominant communities of the lateral lake wetlands. Palustrine wetlands are dominated by emergent wetland vegetation. Dominant species include sedges, rushes (*Juncus* spp.), horsetail (*Equisetum arvense*), cattail (*Typha latifolia*), wild rice (*Zizia aquatica*), common reeds (*Phragmites australis*), bulrushes (*Scirpus microcarpus*), and water potatoes (*Sagittaria latifolia*). Lacustrine vegetation is characterized by submergent and floating vegetation, including duckweed, potamogeton, and algae.

The riverine community also provides habitat for terrestrial wildlife (e.g., moose, elk, white-tailed deer, mule deer, beaver, bats, frogs, dippers). Agricultural communities, predominantly pastureland and hayfields, also provide habitat for migratory birds such as bobolink (*Dolichonyx oryzivorus*) during the summer and waterfowl when fields are flooded in the spring.

Each of these vegetation community types is inhabited by mammalian and avian populations, and to a lesser extent, amphibian and reptilian populations. The wildlife inhabitants are an integral part of the riparian, wetland, and upland communities. Wildlife may use several vegetation community types, and habitat use may extend into the aquatic environment. Wildlife species typical of each of the community types are described in more detail below. In addition to the visible flora and fauna, associated with each of these communities is the below-ground community of macro- and microinvertebrates and fungi that are essential to decomposition, nutrient cycling, and soil formation.

Aquatic Communities

Aquatic communities include high-gradient cold water, midgradient cold water, low-gradient cool and cold water, and warm, cool, and cold water lake communities.

High-gradient cold water communities are characterized by native cutthroat and bull trout, sculpin, possibly whitefish, and introduced rainbow and brook trout. Benthic macroinvertebrate communities include craneflies (Tipulidae), stoneflies (Plecoptera), mayflies (Ephemeroptera), and caddisflies (Tricoptera). Periphyton and some zooplankton are also present.

Midgradient reaches support the fish species listed above, plus whitefish, suckers, squawfish, dace, stonerollers, and introduced salmon. Brown trout are present in the Spokane River. Benthic invertebrate communities include the taxa identified above. Periphyton and zooplankton are also present.

Low-gradient communities include native cutthroat trout, bull trout, and whitefish, and introduced rainbow trout, brook trout, kokanee salmon, and chinook salmon. The lateral lakes also support warm water fish, including largemouth bass, northern pike, yellow perch, black crappie, brown bullhead, and pumpkinseed.

In Coeur d'Alene Lake, both cold and warm water species are present. Native species include cutthroat trout, bull trout, and tench. Introduced cold water species include chinook and kokanee salmon. Warm water species include largemouth bass, northern pike, crappie, yellow perch, bluegill, brown bullhead, pumpkinseed, squawfish, and smallmouth bass.

1.3.4 Trophic Relationships

Figures 1-3 and 1-4 illustrate trophic relationships in the Coeur d'Alene ecosystem. While these figures do not identify rates or magnitudes of energy transfer or specific species essential to the food chain, they do identify groups of organisms essential to maintenance of energy transfer in ecological systems of the basin. These groups must be functional (surviving, reproducing, storing carbon) to provide a food base for the next level. These figures also identify potential exposure pathways of metals to organisms in the environment and potential pathways for indirect exposure or effects. Species characteristic of the more visible trophic groups in each geographic unit are discussed as examples. The species listings are not intended to be complete.

Energy flows from the vegetation, the primary producers, through a web of herbivorous and carnivorous invertebrates to avian and mammalian insectivores, e.g., woodpecker (*Picoides* sp.), robin (*Turdus migratorius*), song sparrow (*Melospiza melodia*), Swainson thrush (*Passerculus sandwichensis*), shrews (*Sorex* sp.). At the top of the upland insectivorous food web (the bottom of Figure 1-4) are avian and mammalian carnivores. Energy also flows from riparian vegetation to mammalian and avian herbivores (e.g., white tailed deer [*Odocoileus virginianus*], mule deer [*Odocoileus hemionus*], elk [*Cervus elaphus*], red squirrel [*Tamiasciurus hudsonicus*], deer mouse [*Peromyscus maniculatus*], meadow vole [*Microtus pennsylvanicus*], cedar waxwing [*Bombycilla cedrorum*], and other neotropical migrants) to mammalian carnivores (e.g., cougar [*Felis concolor*], wolf [*Canis lupus*], marten [*Martes americana*], fisher [*Martes pennanti*]). Omnivorous wildlife species (e.g., ruffed grouse [*Bonasa umbellus*], jays [e.g., *Perisoreus canadensis*], black bear [*Ursus americanus*], coyote [*Canis latrans*]) feed on invertebrates, avian and mammalian insectivores and herbivores, as well as vegetation. In the riparian community, amphibians (frogs) may also be present. These feed on both vegetation and invertebrates, and are preyed upon by avian and mammalian carnivores and omnivores. Soil biota/decomposers appear at the primary level of both the upland and riparian food webs as an energy and nutrient source to vegetation, but at all levels of the food chain, arrows could return to the soil biota/decomposer category, representing energy cycling in the ecosystem.

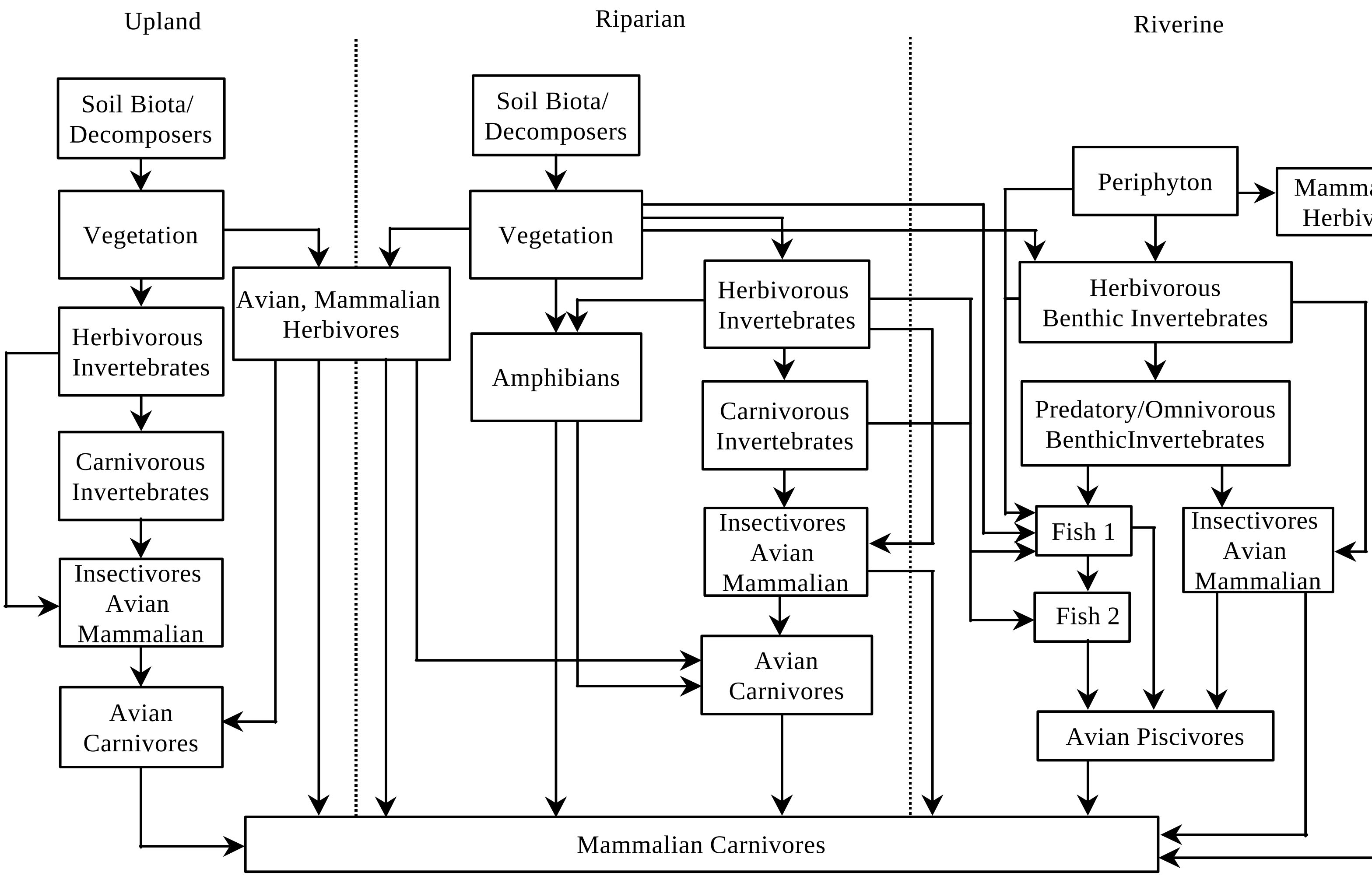

Figure 1-3. Trophic relationships in upland, riparian, and riverine communities of Coeur d'Alene River basin.

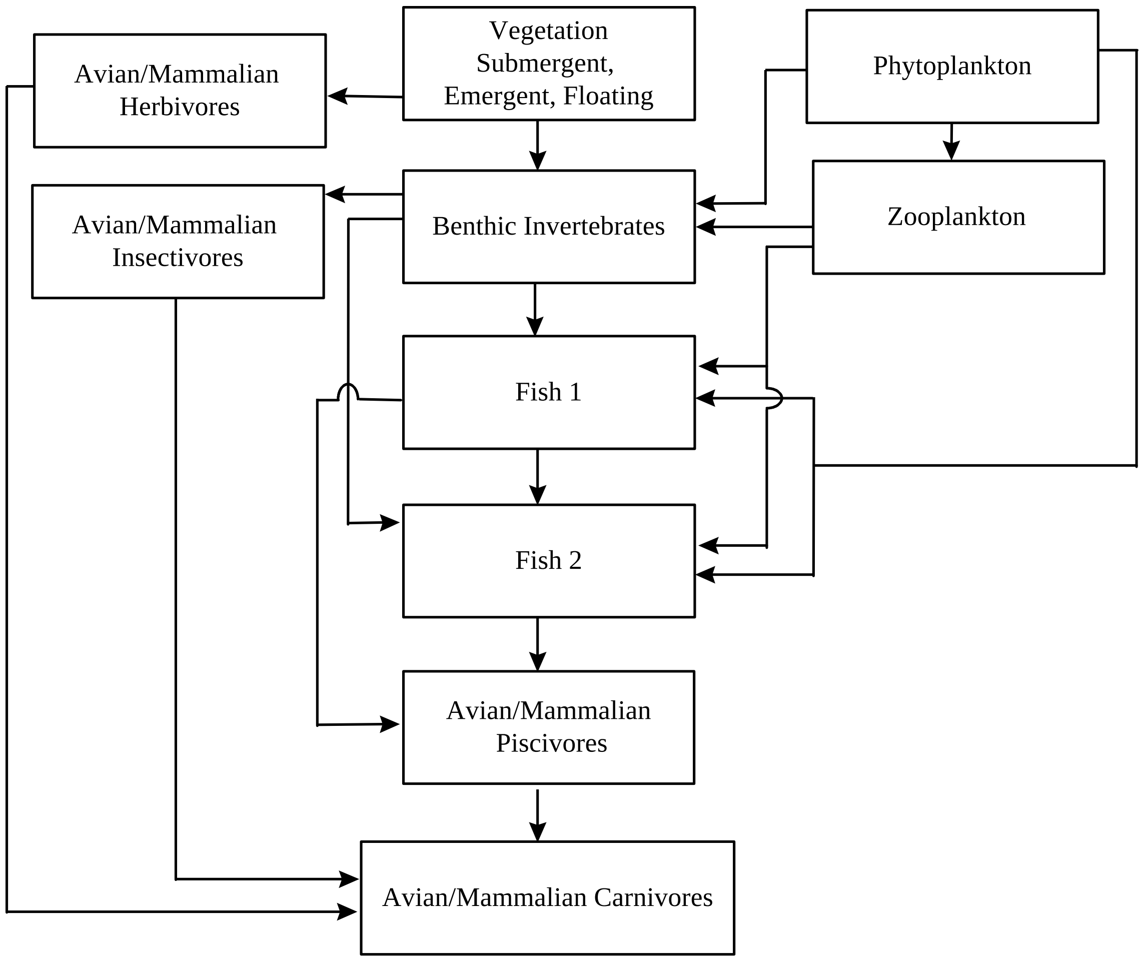

Figure 1-4. Trophic relationships of palustrine and lacustrine communities of the Coeur d'Alene River lateral lakes and Coeur d'Alene Lake.

The riverine food chain derives energy from allochthonous inputs[2] by riparian vegetation as well as phytoplankton and periphyton. Energy generally flows from the primary producers to herbivorous and omnivorous benthic invertebrates, then to carnivorous and omnivorous benthic invertebrates. The aquatic food chain is strongly size dependent — for benthic organisms, predator-prey relationships are constrained by organism size. Benthic invertebrate functional feeding groups include collectors/carnivores, grazers, scrapers, shredders, piercers/suckers, and filter feeders. Water column/benthic feeders (e.g., suckers) feed directly on phytoplankton, periphyton, and detritus. Small fish, insectivorous birds (e.g., dippers [*Cinclus mexicanus*] on headwater and tributary streams; spotted sandpipers [*Actitis macularia*] and swallows

2. Allochthonous material is derived from outside the community. Allochthonous input to streams is organic material derived from the adjacent or upstream terrestrial ecosystem, or material transported from upstream aquatic primary producers.

[e.g., *Hirundo pyrrhonota*] on midgradient streams), and mammals (e.g., bats [*Myotis* sp.]) feed on benthic and terrestrial invertebrates. As with invertebrates, feeding relationships among fish are more dependent on size than species: small fish (e.g., <100 mm) feed primarily on benthic invertebrates (and some terrestrial invertebrates) and periphyton; larger fish (e.g., >100 mm) feed on smaller fish. Avian piscivores (e.g., common merganser [*Mergus merganser*], osprey [*Pandion haliaetus*]) more typically inhabit midgradient reaches of the basin than high-gradient headwater and tributary reaches. Omnivores (e.g., mallards [*Anas platyrhynchos*], wood ducks [*Aix sponsa*], and long-toed salamanders [*Ambystoma macrodactylum*]) feed on invertebrates as well as vegetative food items. Species that are primarily terrestrial also comprise a part of the riverine food chain: mammalian herbivores such as moose *(Alces alces)*, elk, white-tailed deer, and mule deer feed on rooted aquatic macrophytes and periphyton. These species, along with avian piscivores, may ultimately be preyed upon by mammalian carnivores.

In the lower basin, primary producers include aquatic macrophytes, phytoplankton, and periphyton. Allochthonous inputs are substantial as well. Mammalian herbivores in the lower reaches include beaver *(Castor canadensis)* and the larger mammals listed previously. Riparian insectivores include neotropical migrants (e.g., robin, song sparrow, Savannah sparrow [*Passerculus sandwichensis*]), swallows, shrews, long-toed salamanders, toads *(Bufo boreas)*, and bats. The diversity of piscivores is greater in the lower river than in the upper river. Lower river piscivores include birds (e.g., common merganser, red-necked grebe [*Podiceps grisegena*], osprey, loon [*Gavia immer*], great blue heron [*Ardea herodias*], kingfisher [*Megaceryle alcyon*]), mammals (e.g., mink [*Mustela vison*], river otter [*Lutra canadensis*]), and reptiles. Avian and mammalian carnivores in the lower river system include great horned owl *(Bubo virginianus)*, western screech owl *(Otus asio)*, northern harrier *(Circus cyaneus)*, other accipiters, and wolf. Omnivores inhabiting the lower river system include bald eagle *(Haliaeetus leucocephalus)*, red tailed hawk *(Buteo jamaicensis)*, sharp shinned hawk *(Accipiter striatus)*, common goldeneye *(Bucephala clangula)*, raccoon *(Procyon lotor)*, coyote (*Canis latrans*), black bear (*Ursus americanus*), king snake (*Lampropeltis getula*), garter snake (*Thamnophis sirtalis*), and long-toed salamander.

In the palustrine and lacustrine communities of the lateral lakes and Coeur d’Alene Lake, primary producers include abundant submergent, emergent [e.g., horsetail, cattail, wild rice, giant reed grass (*Phragmites communis*), and water potatoes], and floating (e.g., duckweed, potamogeton, algae) vegetation, as well as phytoplankton. Shrub-scrub vegetation (e.g., spiraea, alder) in adjacent palustrine areas provides riparian habitat and allochthonous inputs to the aquatic system. Avian herbivores in the lateral lakes communities include the Canada goose (*Branta canadensis*), mallard, tundra swan (*Cygnus columbianus*), American wigeon (*Anas americana*), green-winged teal (*Anas crecca*), and American coot (*Fulica americana*). Mammalian herbivores include muskrat (*Ondatra zibethicus*), beaver, deer, elk, and moose. Insectivores include snipe (*Capella gallinago*), killdeer (*Charadrius vociferus*), black tern (*Chlidonias niger*), swallows, blackbirds (e.g., *Agelaius* spp.), bats, and dragonflies (Odonata). The piscivores common to the lower river also feed in the lateral lakes. Carnivores include peregrine falcon (*Falco peregrinus*), American kestrel (*Falco sparverius*), northern harriers (*Circus cyaneus*), and mink. Omnivores include the diving ducks (ruddy duck [*Oxyura jamaicensis*], canvasback [*Aythya valisineria*], redhead

[*Aythya americana*], common goldeneye, lesser scaup [*Aythya affinis*]) in the lacustrine areas; red-tailed hawk, raven (and other corvids), snakes, amphibians, coyote and raccoon in the palustrine areas; and gulls (California [*Larus californicus*], ring-billed [*Larus delawarensis*]) and bald eagle in both lacustrine and palustrine communities.

1.4 DATA SOURCES

The large amount of data relied upon by the Trustees and presented in this report of injury assessment derive from numerous sources, including existing/historical data, reports, and scientific literature. Data sources included:

- State of Idaho data and reports on water quality, suspended sediments, fisheries, and wildlife

- federal agencies, including U.S. Environmental Protection Agency (U.S. EPA) Bunker Hill Remedial Investigation/Feasibility Study (RI/FS) documents, Coeur d'Alene Basinwide RI/FS reports and databases, U.S. DOI wildlife data, U.S. Forest Service (USFS) forestry, stream, and mine inventory data, U.S. Bureau of Land Management (U.S. BLM) mine and mine waste inventory and removal data and vegetation mapping data, U.S. Geological Survey (USGS) surface water monitoring data and minerals exploration data

- the Coeur d'Alene Tribe, fisheries and lake management data

- university research, including work by faculty and graduate students at the University of Idaho, as well as other colleges and universities

- private (industry) data, including nonproprietary documents prepared by the mine companies and contractors for the mine companies.

The above information was supplemented, as necessary, with data collected as part of focused NRDA studies designed to answer specific questions related to evaluation of injuries to natural resources and determination of pathways of exposure to hazardous substances.

Sources of data and information used in each chapter are cited at the end of each chapter. Studies conducted as part of the NRDA injury assessment are identified and the final reports are provided on the enclosed compact disc. During the preparation of this document, many of the NRDA injury studies were published or accepted for publication in peer-reviewed scientific journals. The versions included on the enclosed compact disc are the versions that were used in preparing this document and are not necessarily the final versions submitted for publication.

Collection and analysis of environmental samples from the Coeur d'Alene River basin, and in particular, collection and analysis of samples for the Coeur d'Alene Basin Remedial Investigation/Feasibility Study, was ongoing at the time that this document was prepared. In general, data that were available for use by fall 1999 were included in the analyses presented in this report; data collected or released for public use subsequently were not included.

1.5 REPORT ORGANIZATION AND SUMMARY OF PRINCIPAL FINDINGS

Chapter 2 characterizes the multiple **sources** from which hazardous substances have been released in the Coeur d'Alene River basin and describes the nature of the releases. Sources that have released or continue to release hazardous substances to the Coeur d'Alene River basin include mining and mineral processing operations; waste rock, tailings dumps, and adits at mine and mill sites; floodplains, and river and lake beds and banks containing tailings and mixed tailings and alluvium; and eroding hillsides historically contaminated by smelter emissions. Source materials include waste rock, mill tailings, mixed tailings and alluvium, concentrates, mine drainage waters, smelter emissions, and flue dust. Hazardous substances released are the metals and metalloids in mining waste. Types of releases include historical disposal of tailings to creeks, rivers, and floodplains; historical smelter emissions; and ongoing releases of hazardous substances from waste rock and tailings deposits and sites where tailings have come to be located throughout the Coeur d'Alene River basin.

The information presented in Chapter 2 demonstrates the following:

- Hazardous substances, including cadmium, lead, zinc, and other hazardous metals and metalloids, have been and continue to be released as a result of mining and mineral processing operations in the Coeur d'Alene River basin. Releases of hazardous substances to the Coeur d'Alene River basin began in the 1880s and continue to the present. Releases will continue for the foreseeable future absent large-scale remediation or restoration.

- Waste rock, mill tailings, and drainage from underground mine workings are the primary sources of hazardous substances in the Coeur d'Alene River basin. Historically, smelter emissions, transported by air pathways, were a primary source of hazardous substances to the hillsides surrounding the Bunker Hill smelter. The predominant secondary sources of hazardous substances are bed, bank, and floodplain sediments and upland soils of the Coeur d'Alene River basin that have been contaminated by releases from the primary sources.

- The many releases of hazardous substances from mines and mineral processing facilities to hillsides, floodplains, and streams of the basin and subsequent transport of wastes from source areas via pathways have resulted in the inextricable commingling of hazardous substances from numerous sources, with subsequent distribution of hazardous substances throughout the Coeur d'Alene River basin.

Chapter 3 presents the **pathways** by which natural resources of the Coeur d'Alene River basin are exposed to hazardous substances released from mining and mineral processing operations. The pathway determinations presented in this chapter are based on data collected by the Trustees and by other researchers in the basin.

The information presented in Chapter 3 demonstrates the following:

- Surface water serves as a critical transport and exposure pathway of dissolved and particulate hazardous substances to soil, aquatic, and terrestrial biological resources and downstream surface water resources. Surface waters of the Coeur d'Alene River basin downstream of mining and mineral processing facilities have been and continue to be exposed to elevated concentrations of hazardous substances, including cadmium, lead, and zinc. Because of natural downstream transport mechanisms, surface waters throughout much of the Coeur d'Alene River basin — including the South Fork Coeur d'Alene River, the Coeur d'Alene River, Coeur d'Alene Lake, and Canyon, Ninemile, Moon, and Pine creeks and other tributaries to the South Fork Coeur d'Alene River — are exposed to elevated concentrations of hazardous substances.

- Sediment in the water column and in the beds and banks of Coeur d'Alene River basin drainages downstream of mining and mineral processing facilities has been and continues to be a transport and exposure pathway. Bed and bank sediments throughout the basin contain elevated concentrations of hazardous substances, including cadmium, lead, and zinc. Contaminated sediments are an ongoing pathway for downstream movement of hazardous substances through natural processes. Contaminated streambed sediment exposes fish, periphyton, and aquatic invertebrates to hazardous substances. Contaminated sediment re-deposited on floodplains and on vegetation surfaces is an important cause of exposure of wildlife and vegetation to hazardous substances.

- Floodplain soils have been and continue to be a transport and exposure pathway. Floodplain soils and wetland sediments have become contaminated with hazardous substances in direct discharge of wastes to the floodplain, and through deposition of contaminated sediments in natural hydrological processes. Floodplain soils are contaminated with hazardous substances such as cadmium, lead, and zinc in riparian areas downstream of mining and mineral processing facilities, including riparian areas of the South Fork Coeur d'Alene River, the Coeur d'Alene River, and Canyon, Ninemile, Moon, and Pine creeks. Contaminated floodplain soils serve as an ongoing transport pathway to downstream resources through mobilization by surface waters. Floodplain soils contaminated with hazardous substances serve as a pathway by which vegetation and soil biota are exposed to hazardous substances. Wildlife are exposed to hazardous substances through direct ingestion of soil and sediment and ingestion of soil and sediment adhering to vegetation.

- Although data are not available throughout the Coeur d'Alene River basin, available information illustrates that groundwater in certain locations is a pathway by which hazardous substances are leached from contaminated floodplain deposits and transported to downgradient surface waters. In addition, surface waters containing hazardous substances are in contact with shallow groundwater aquifers in floodplains. Surface waters containing hazardous substances also serve as a pathway to shallow groundwater.

- Biological resources serve as contaminant exposure pathways through dietary exposure. Contaminated periphyton, aquatic invertebrates, and fish are exposure routes of hazardous substances to higher trophic level consumers. Aquatic vegetation containing or coated with elevated concentrations of lead exposes waterfowl through their diets. Wildlife also are exposed to hazardous substances through consumption of contaminated prey.

Chapter 4 presents the determination of injury to **surface water resources**. Surface water resources addressed include the South Fork Coeur d'Alene River, certain tributaries to the South Fork Coeur d'Alene River, the lower Coeur d'Alene River, the lateral lakes, and Coeur d'Alene Lake.

The information presented in Chapter 4 demonstrates the following:

- Sufficient concentrations of hazardous substances exist in pathway resources now, and have in the past, to expose surface water resources to hazardous substances.

- Sufficient concentrations of hazardous substances exist in surface water resources now, and have existed in the past, to exceed federal, state, and tribal water quality criteria developed for protection of aquatic life. Therefore, surface water resources are injured.

- Exceedences of water quality criteria have been documented from the upper reaches of the South Fork Coeur d'Alene River and its tributaries to the mainstem Coeur d'Alene River, including the lateral lakes, and in Coeur d'Alene Lake. Surface water is injured in the South Fork Coeur d'Alene River from downstream of Daisy Gulch to the confluence with the North Fork Coeur d'Alene River. Canyon Creek, Ninemile Creek, and Pine Creek are also injured from locations in each stream adjacent to the uppermost mine or mill site to the confluence of each tributary with the South Fork Coeur d'Alene River. Surface waters of the lower Coeur d'Alene River from the North Fork Coeur d'Alene River confluence to Coeur d'Alene Lake are injured. Surface waters of the lateral lakes and Coeur d'Alene Lake are also injured. In addition, the following tributaries of the South Fork Coeur d'Alene River, Canyon Creek, and Pine Creek are injured from the location of the uppermost mine or mill site to the mouth: Grouse Gulch, Moon Creek, Milo Creek, Portal Creek, Deadwood Gulch/Bunker Creek, Government Gulch, Gorge Gulch, Highland Creek, Denver Creek, and Nabob Creek.

- Concentrations of hazardous substances in surface water resources downstream of releases are sufficiently elevated that surface water serves as a pathway of injury to downstream surface waters.

- Concentrations of hazardous substances in surface water resources are sufficient to cause injury to aquatic biological resources, and to serve as a pathway of injury to wildlife and to aquatic biological resources.

Chapter 5 presents data on the condition of the **sediment** resources of the Coeur d'Alene River basin. Sediments are materials deposited by water and include suspended sediments in the water column, and bed, bank, and floodplain sediments. Sediments carried in the water column are suspended sediments. Sediment resources are defined by DOI NRDA regulations both as geologic resources [43 CFR §11.14 (s)] and as a component of surface water resources [43 CFR § 11.14 (pp)]. However, because sediments represent a distinct component of the ecosystem, data on sediments are discussed separately from surface water.

The information presented in Chapter 5 demonstrates the following:

- Metals in streambeds, banks, and floodplains are remobilized through natural hydrologic processes such as scouring, erosion, and resuspension during high water events.

- Sediments of the Coeur d'Alene River basin at and downstream of mining and mineral processing facilities contain substantially elevated concentrations of hazardous substances, including cadmium, lead, and zinc. Sediment contamination is pervasive in the beds, banks, and floodplains of the basin.

- Concentrations of hazardous substances in Coeur d'Alene River basin sediments exceed thresholds associated with adverse effects for benthic invertebrates. As concentrations of hazardous substances in these sediments increase, concentrations of hazardous substances in biofilm (attached algae, bacteria, and associated fine detrital material that adheres to substrates in surface waters and is a food source for higher trophic level consumers), benthic invertebrates, and fish in the basin increase. Sites with the highest concentrations of metals in water, sediment, biofilm, and benthic invertebrates were also the sites where fish populations were reduced, mortality was observed, and tissues contained elevated concentrations of metals.

- Coeur d'Alene River basin sediments containing elevated concentrations of lead and other hazardous substances are ingested by migratory waterfowl. Ingestion of contaminated sediments causes death, physiological malfunction, and physiological deformation of wildlife resources. Sufficient concentrations of hazardous substances are present in sediments to cause injury to biological resources, and therefore sediments are injured.

Chapter 6 describes injuries to **wildlife** resources of the Coeur d'Alene River basin that have resulted from exposure to hazardous metals released from mining and mineral processing facilities.

The information presented in Chapter 6 demonstrates the following:

- Sufficient concentrations of hazardous substances exist in pathway resources to expose wildlife resources. The sources of hazardous substance exposure to wildlife are releases of lead and other metals from mining and mineral processing activities. Hazardous substances are transported from the South Fork Coeur d'Alene River basin in surface water, soil, and sediment to the lower Coeur d'Alene River basin.

- Hazardous substances in sediments are accumulated in plants, invertebrates, fish, mammals, and birds that are consumed by other species of birds and mammals in the Coeur d'Alene River basin. Food chain exposure is an important pathway for lead and other metals in the Coeur d'Alene River basin. Hazardous substance concentrations in pathway resources are sufficient to expose wildlife via ingestion of contaminated sediment and forage and prey items.

- The results of field investigations and controlled laboratory experiments demonstrate that death, physiological malfunctions, and physical deformation injuries to wildlife of the Coeur d'Alene River basin have occurred and continue to occur as a result of exposure to lead in Coeur d'Alene River basin sediments. Adverse effects that have been caused by lead exposure and have been observed in migratory birds in the field include death; physiological malfunctions, including changes in parameters related to impaired blood formation and impaired growth; and physical deformations, including gross and histopathological lesions.

- Laboratory studies demonstrated a dose-response relationship between the magnitude of exposure to Coeur d'Alene River basin sediment and physiological malfunctions such as biochemical changes in waterfowl. The injury assessment studies demonstrated a causal relationship between increasing sediment ingestion and adverse changes in parameters related to blood formation in multiple species of waterfowl.

- Ingestion of lead-contaminated sediments is the pathway and cause of the injuries to migratory birds in the basin. Injury studies were designed to explicitly assess whether the observed deaths and sublethal injuries were caused by other agents, including lead artifacts (e.g., shot/sinkers), disease (e.g., aspergillosis, avian cholera), or other factors (e.g., trauma). Detailed evaluation of field observations and diagnostic histological studies demonstrated that the cause of the injuries was exposure to lead-contaminated sediments. Therefore, injuries to migratory birds are caused by hazardous substances, particularly lead, released from mining and mineral processing facilities.

Chapter 7 presents the assessment of injury to **fish** resources of the Coeur d'Alene River basin, focusing on the South Fork Coeur d'Alene River, the Coeur d'Alene River, and tributaries to the South Fork Coeur d'Alene and Coeur d'Alene rivers. Fish resources have been injured in the South Fork Coeur d'Alene River, Canyon Creek, and Ninemile Creek, as well as other stream/river reaches affected by releases of hazardous substances from mining and mineral processing operations.

The information in Chapter 7 demonstrates the following:

- Sufficient concentrations of hazardous substances, particularly cadmium and zinc, exist in pathway resources now, and have existed in the past, to expose and injure fish of the Coeur d'Alene River basin. Concentrations of hazardous substances in surface water (including suspended and bed sediments), biofilm (attached algae and associated detritus), and aquatic invertebrates are elevated and are pathways of metals exposure and injury to fish.

- Fish resources of the Coeur d'Alene River basin are injured as a result of exposure to hazardous metals, particularly cadmium and zinc, which are highly toxic to fish. Fish resources have been injured in the South Fork Coeur d'Alene River, Canyon Creek, Ninemile Creek, and the mainstem Coeur d'Alene River, as well as other stream and river reaches affected by releases of hazardous substances from mining and mineral processing operations.

- Injured fish resources include resident, fluvial, and adfluvial species of the South Fork Coeur d'Alene River, the lower Coeur d'Alene River, and Coeur d'Alene Lake.

- Concentrations of cadmium and zinc in surface water of the South Fork Coeur d'Alene River, Canyon Creek, and Ninemile Creek exceed chronic and acute water quality criteria for the protection of aquatic life and are sufficient to cause acute mortality to trout.

- Laboratory and field studies demonstrated that salmonids avoid water containing zinc at concentrations that occur in the South Fork Coeur d'Alene River, Canyon Creek, Ninemile Creek, and the lower Coeur d'Alene River as far downstream as Harrison, and Coeur d'Alene Lake.

- In controlled laboratory studies, ingestion by juvenile cutthroat trout of aquatic invertebrates from the South Fork and lower Coeur d'Alene rivers that were contaminated with cadmium, lead, and zinc was found to cause increased mortality, reduced feeding activity (a behavioral abnormality), and histopathological lesions (physiological deformation).

- Injuries to fish include death, as confirmed by *in situ* bioassays and laboratory toxicity testing; behavioral avoidance, as confirmed by laboratory tests using fish placed in testing chambers in controlled laboratory conditions and by field tests; and physiological malfunctions, including effects on growth, and other physical deformations such as histopathological lesions, as confirmed by laboratory testing.

- Populations of trout species and other fish species have been reduced or eliminated by elevated concentrations of hazardous substances in the South Fork Coeur d'Alene River and its tributaries. The fish population data are consistent with the conclusion that hazardous substances released from mining operations are causing injuries to fish.

- Other possible causes of fish injuries (such as channelization, logging, fires, introduction of exotic species) were evaluated. Field studies were designed to include sampling of reference locations to enable explicit consideration of many of these possible factors. The nature, extent, and pattern of fish injuries and population responses, coupled with data showing that surface water causes acute lethality and other injuries to fish, demonstrate that releases of metals (particularly zinc and cadmium) injure fish.

Chapter 8 presents the determination of injury to **benthic macroinvertebrate** resources of the Coeur d'Alene basin. Benthic macroinvertebrates are invertebrates that live on stream or lake bottoms. Benthic macroinvertebrate resources have been injured in the South Fork Coeur d'Alene River, Canyon Creek, and Ninemile Creek, as well as other stream and river reaches affected by releases of hazardous substances from mining and mineral processing operations.

Specifically, the information presented in Chapter 8 demonstrates the following:

- Benthic macroinvertebrates in the South Fork Coeur d'Alene, the Coeur d'Alene River, Coeur d'Alene Lake, Canyon Creek, and Ninemile Creek, as well as other tributary reaches, are exposed to elevated concentrations of cadmium, lead, and zinc in surface water, sediment, and biofilm.

- The metal concentrations to which benthic macroinvertebrates of the South Fork Coeur d'Alene, the Coeur d'Alene River, Coeur d'Alene Lake, Canyon Creek, and Ninemile Creek are exposed are well above concentrations shown to cause toxicity.

- Toxicity tests using water and sediment demonstrate that water and sediment collected from the Coeur d'Alene River basin downstream of mining activity are toxic to invertebrates under controlled laboratory conditions.

- Benthic macroinvertebrate communities in the South Fork Coeur d'Alene, Canyon Creek, Ninemile Creek, and other stream/river reaches are adversely affected by metals. Specifically, metal-sensitive species are largely absent from the invertebrate communities of these waterways downstream of mining activity. Historical data also demonstrate that the invertebrate communities in the mainstem Coeur d'Alene River and Coeur d'Alene Lake have been adversely affected in the past. Recent data on the communities in these areas are not available to confirm that the effects are continuing, but hazardous substance concentrations in surface water and sediment of the Coeur d'Alene River and Lake remain elevated. In addition, chironomid mouthpart deformities resulting from metals exposure may be ongoing in the South Fork and mainstem Coeur d'Alene rivers.

- The adverse effects on the invertebrate community have been occurring since at least the 1930s. Reductions in metals concentrations over time have resulted in an improvement in the benthic macroinvertebrate community, but the communities of the South Fork Coeur d'Alene River, Canyon Creek, and Ninemile Creek remain adversely affected.

Chapter 9 presents the determination of injury to **riparian resources**. The information presented in this chapter and previous chapters demonstrates that riparian resources of the Coeur d'Alene River basin have been injured by releases of hazardous substances from mining and mineral processing operations. Specifically:

- Sufficient concentrations of cadmium, lead, and zinc exist in pathway resources to transport hazardous substances to floodplains of the Coeur d'Alene River basin.

- Concentrations of hazardous substances, particularly cadmium, lead, and zinc, in exposed floodplain soils of Canyon Creek, Ninemile Creek, and the South Fork Coeur d'Alene River are significantly greater than concentrations in reference area soils. Concentrations of hazardous substances in lower Coeur d'Alene River basin sediments are also substantially elevated relative to the reference soils.

- Floodplain soils of Canyon Creek, Ninemile Creek, and the South Fork Coeur d'Alene River are phytotoxic (i.e., cause toxicity to plants) relative to control soils. Plant growth performance in field-collected assessment soils was measured under controlled laboratory conditions. Plant growth in contaminated soils was reduced relative to control soils, and plant growth was significantly negatively correlated with concentrations of hazardous substances in the soils.

- Concentrations of hazardous substances in floodplain soils of assessment reaches exceed phytotoxic thresholds identified in the scientific literature, and the observed reductions in plant growth are consistent with the phytotoxic effects of zinc and other heavy metals reported in the scientific literature.

- In the riparian zones of Canyon Creek, Ninemile Creek, and the South Fork Coeur d'Alene River, extent of vegetation cover, species richness, and vegetation structural complexity are significantly negatively correlated with concentrations of hazardous substances in soils; percent cover of bare ground is significantly positively correlated with concentrations of hazardous substances. In other words, increased concentrations of soil metals were related to increased bare ground and reduced vegetation.

- Phytotoxic concentrations of hazardous substances in floodplain soils have resulted in significant and substantial reductions in riparian vegetative cover and an increase in the amount of bare ground in the riparian zones of Canyon Creek, Ninemile Creek, and the South Fork Coeur d'Alene River.

- The sources and pathways of metals to floodplain soils of Pine and Moon creeks are similar to the sources and pathways of metals to floodplain soils of Canyon and Ninemile creeks and the South Fork Coeur d'Alene River, and the concentrations of hazardous substances are similar to concentrations determined to be phytotoxic on Canyon and Ninemile creeks and the South Fork Coeur d'Alene River. Therefore, injury to riparian resources of Pine and Moon creeks is inferred to have resulted from phytotoxic concentrations of hazardous substances in floodplain soils.

- Soil phytotoxicity and reductions in vegetation cover have resulted in deterioration of ecological functions, including habitat for all biological resources that are dependent on riparian habitats in the basin; growth media for plants and invertebrates; primary and secondary productivity, carbon storage, nitrogen fixing, decomposition, and nutrient cycling; soil organic matter and allocthonous energy (i.e., carbon from decomposing plant matter) to streams; geochemical exchange processes; food and cover (thermal cover, security cover) for fish, migratory birds, and mammals; feeding and resting areas for fish, migratory birds, and mammals; the migration corridor provided by the riparian zone; habitat for macroinvertebrates; soil/bank stabilization and erosion control; and hydrograph moderation.

Chapter 10 presents an initial **quantification of injury** to natural resources, including an analysis of **baseline conditions**. The effects of the releases of hazardous substances are quantified in terms of the reduction from the baseline condition in the quantity and quality of services provided by the injured resources [43 CFR 11.70 (a)]. Injury quantification includes determination of the baseline condition and baseline services of the injured resources, determination of the extent of the injuries and the reduction in services resulting from the injuries, and determination of the recoverability of the injured resources [43 CFR 11.70 (c)].

Baseline refers to the conditions that would have existed had the releases of hazardous substances not occurred [43 CFR § 11.14 (e)]. The injured resources of the Coeur d'Alene River basin, including surface water, soil and sediment, wildlife, aquatic biota, and riparian resources, are ecologically interdependent and provide interdependent services. The baseline services provided collectively by these resources are inseparable at the ecosystem level. Individually, services include the following:

- *Surface water services*, such as habitat for migratory birds and their supporting ecosystem; habitat for fish and their supporting ecosystem; habitat for benthic macroinvertebrates and aquatic, semiaquatic, and amphibious animals; water, nutrients, and sediments for riparian vegetation and its supporting ecosystem; nutrient cycling; geochemical exchange processes; primary and secondary productivity and transport of energy (food) to downstream and downgradient organisms; growth media for aquatic and wetland plants; a migration corridor; and cultural services.

- *Sediment services*, such as providing habitat services for all biological resources that are dependent upon the aquatic habitats in the basin. In addition, bed sediment services contribute to services provided by surface water, including suspended sediment transport processes, security cover for fish and their supporting ecosystems, primary and secondary productivity, geochemical exchange processes, nutrient cycling and transport, and cultural services.

- *Services provided by floodplain soils and sediments*, such as habitat for all biological resources that are dependent upon riparian or floodplain wetland habitats in the basin. Floodplain soils and sediments provide habitat for migratory birds and mammals; habitat for soil biota; growth media for plants and invertebrates; primary productivity, carbon storage, nitrogen fixing, decomposition, and nutrient cycling; soil organic matter and energy (food) to streams; hydrograph moderation; geochemical exchange processes; and cultural services.

- *Migratory bird services*, including providing prey for carnivorous and omnivorous wildlife, as well as existence values, food, and recreational opportunities for humans, and cultural services.

- *Fish services*, including providing food for other biota, as well as existence values and recreational opportunities for humans, and cultural services.

- *Riparian vegetation* provides primary productivity; food and cover (thermal cover, security cover) for fish and migratory birds and mammals; feeding and resting areas for fish, and migratory birds and mammals; the migration corridor provided by the riparian zone; habitat for macroinvertebrates; nutrient cycling; soil and bank stabilization and erosion control; hydrograph moderation; and cultural services.

The services listed above are interdependent and interact to create a functional ecosystem. The injuries to natural resources described in previous chapters have reduced individual resource services and services provided at the ecosystem level. The high degree of overlap in services affected by the injuries results from the fact that contaminated surface water and soil/sediment resources are now ubiquitous in parts of the basin downgradient of mining and milling operations, and the services provided by these resources are integral parts of an ecologically interdependent ecosystem. Although there are numerous attributes and services that have been reduced and that could be quantified individually, instead, injuries were quantified at the habitat level [43 CFR 11.71 (l)(1)].

Surface water and soil/sediment resources provide an intrinsic part of the habitat for aquatic biota, wildlife, and vegetation, but in the Coeur d'Alene River basin, injuries to fish and other aquatic biota, wildlife, and riparian vegetation are *caused* by hazardous substances to which they are exposed in injured surface water, soils, and sediments. The injured surface water, soils, and sediments therefore have diminished ability to sustain aquatic biota, vegetation, and habitat for wildlife relative to baseline. The area where hazardous metal concentrations in surface water and soils/sediment resources exceed baseline concentrations and that have reduced ability to sustain aquatic biota, vegetation, and habitat for wildlife was quantified relative to baseline [43 CFR 11.71 (h)(4)(i) and (k)(1,2)]. As part of this determination, baseline conditions for riparian vegetation cover, structure, and composition were also determined, since restoration of riparian vegetation in the upper basin is crucial to restoration of the Coeur d'Alene River basin ecosystem and services provided collectively by the injured resources.

For baseline determination, floodplain soils and sediments, and bed, bank, and suspended sediments, from the Coeur d'Alene River basin were assessed collectively. Mean baseline concentrations for soil and sediment are 30 mg lead/kg dry weight of sediment (dw), 0.61 mg cadmium/kg dw, and 63 mg zinc/kg dw.

For surface water baseline determination, the Coeur d'Alene River basin was divided into three areas of ore deposit type. Median values for dissolved cadmium, lead, and zinc in the upper South Fork Coeur d'Alene River basin were 0.06, 0.15, and 5.35 µg/L, respectively. Median values for dissolved cadmium, lead, and zinc in the Page-Galena mineral belt area were 0.1, 0.44, and 9.04 µg/L, respectively. Median values for dissolved cadmium, lead, and zinc in the Pine Creek drainage were 0.03, 0.11, and 3.68 µg/L, respectively. For the South Fork Coeur d'Alene River basin as a whole, median baseline concentrations for the three metals were 0.06, 0.18, and 6.75 µg/L, respectively.

The riparian vegetation baseline data represent a range of site types reflecting elevational gradients, hydrologic gradients, valley shape, width, and orientation, and successional stages of patches of vegetation within the areas sampled. The characterization of riparian vegetation baseline condition focuses on parameters directly related to the injuries quantified: mean percent cover of bare ground (3.0%), mean percent cover of vegetation (139%), mean species richness (17 total species), and mean structural complexity (four layers present).

Injury to surface water and soils/sediment resources and the associated service reductions were quantified as the total area where hazardous metal concentrations exceed baseline and have reduced the ability to sustain aquatic biota, vegetation, and habitat for wildlife relative to baseline [43 CFR § 11.71 (h)(4)(i) and (k)(1-2)]. This approach recognizes the multiple primary and secondary service losses.

Surface water injury was quantified as the river miles in which dissolved concentrations of cadmium, lead, or zinc exceed water quality criteria for the protection of aquatic biota. Injured riverine surface waters include a total of 181 km (113 miles):

- 107 km (67 miles) of the South Fork and mainstem Coeur d'Alene rivers from downstream of Daisy Gulch to the mouth at Coeur d'Alene Lake
- 11.3 km (7.0 miles) of Canyon Creek from approximately Burke to the mouth
- 11.6 km (7.2 miles) of East Fork and mainstem Ninemile Creek from the Interstate-Callahan Mine to the mouth
- 2.7 km (1.7 miles) of Milo Gulch from the Sullivan Adits to the mouth
- 4.0 km (2.3 miles) of Grouse Gulch from the Star Mine waste rock dumps to the mouth
- 5.0 km (3.1 miles) of Moon Creek from the Charles Dickens Mine/Mill to the mouth
- 0.9 km (0.5 miles) of Portal Gulch from the North Bunker Hill West Mine to the mouth
- 4.7 km (2.9 miles) of Deadwood Gulch/Bunker Creek from the Ontario Mill to the mouth
- 4.1 km (2.5 miles) of Government Gulch from the Senator Stewart Mine to the mouth
- 16.8 km (10.4 miles) of the East Fork and mainstem Pine Creek from the Constitution Upper Mill to the mouth
- 5.2 km (3.2 miles) Highland Creek from the Highland Surprise Mine/Mill and the Sidney (Red Cloud) Mine/Mill to the mouth
- 5.3 km (3.3 miles) Denver Creek from the Denver Mine to the mouth
- 0.5 km (0.3 miles) Nabob Creek from the Nabob Mill to the mouth.

In addition, injured surface waters include:

- the lateral lakes and wetlands
- Coeur d'Alene Lake from near Conkling Point to the lake's outlet at the Spokane River.

The extent of injury to floodplain soils and sediments in the upper basin was quantified as the area over which hazardous substance concentrations exceed baseline and have reduced the soil's ability to sustain vegetation and habitat for wildlife relative to baseline [43 CFR § 11.71 (h)(4)(i) and (k)(1-2)]. Based on the known patterns of hazardous substance release, transport, contamination, and toxicity at the vegetation community level, vegetation cover mapping was used as a conservative indicator of soils with reduced ability to sustain vegetation and habitat for biota relative to baseline. The total area of barren or substantially devegetated floodplains along the South Fork Coeur d'Alene River downstream of the Canyon Creek confluence, Canyon Creek, Ninemile Creek, Moon Creek, and Pine Creek is 1,522 acres. This barren or sparsely vegetated area comprised greater than 80% of the available nonurban floodplain.

The extent of injury to soils and sediments of the lower basin was quantified as the area in floodplain in which hazardous substance concentrations exceed baseline concentrations an have reduced ability to provide suitable (nontoxic) habitat for wildlife relative to baseline [43 CFR 11.71 (h)(4)(i) and (k)(1-2)]. Modeled predictions of lead concentration in surficial sediments were used to estimate the area of contaminated sediments that exceeded four threshold concentrations: 30 ppm lead, the geometric mean baseline concentration; 175 ppm lead, the upper 90th percentile of baseline concentration; 530 ppm lead, a lowest observed effect level for waterfowl; and 1,800 ppm lead, a lethal effect level for waterfowl. The area in which sediment lead concentrations exceed the lethal threshold is 15,368 acres, the area in which sediment lead concentrations exceed the lowest observed effect level for waterfowl is 18,298 acres, and the area in which sediment lead concentrations exceed the 90th percentile of baseline concentration is 18,558 acres. The area in which sediment lead concentrations exceed the geometric mean baseline concentration is 18,608 acres.

None of the existing surface water data indicate declining hazardous substance concentrations with time during the past two decades. There is no evidence that maximum, minimum, or mean zinc concentrations have declined: almost all of the concentrations measured in the South Fork Coeur d'Alene River downstream of Canyon Creek, and all of the concentrations measured at the mouths of Canyon and Ninemile creeks, exceeded acute zinc aquatic water quality criteria at all times that samples were collected over the last 30 years. Although patterns of recovery may be obscured by variability in flow and climate, the data overall do not indicate that water quality is improving.

There has been no consistent sampling of sediments over time at designated locations as there has been for surface water. In general, however, sediment data collected recently (1990s) from the lower basin are consistent with data collected previously (1970s and 1980s). There is no indication that sediment concentrations of cadmium, lead, and zinc are decreasing.

Recovery of fish, benthic invertebrate, wildlife, and riparian resources is dependent on recovery of suitable habitat quality, which requires recovery of surface water, sediment, and floodplain soil resources. Once surface water, sediment, and floodplain soil resources have recovered to a condition that will support biological resources, recovery of the Coeur d'Alene River basin ecosystem will be constrained by the rate of natural physical and biological recovery (vegetation reestablishment and physical habitat rebuilding by natural hydrologic, geologic, and biological processes).

For wildlife resources of the lower basin, recovery will occur rapidly once sediments are nontoxic, since physical modifications resulting from sediment injuries are not negatively affecting habitat use. When surface water and sediment conditions improve, benthic macroinvertebrates and fish from upstream clean reaches and clean tributaries will colonize recovered areas naturally and rapidly. Recovery time for fish also will include time required for natural reestablishment of physical features of habitats that were degraded as a result of the injuries, such as overhanging banks, vegetative overhang, and pools created by woody debris and roots. Natural recovery of the aquatic physical habitat of the upper basin will depend strongly on recovery of riparian resources.

Natural recovery time for riparian resources will depend on time required for floodplain soils to become diluted to nonphytotoxic levels, followed by primary vegetation succession, organic soil development, and development of vertically and horizontally diverse vegetation communities. Natural recovery of riparian resources includes development of vegetation that will overhang the stream, modulate stream temperatures, and provide security cover for fish. It includes recovery of riparian vegetation to the point where the vegetation provides habitat structure (e.g., large woody debris; bank stabilization) and a source of energy (i.e., detritus) to the aquatic ecosystem. It also includes reestablishment of diverse early and late successional vegetation and the expected range of terrestrial habitat features (e.g., mature tree boles for tree-cavity nesting birds).

Throughout the Coeur d'Alene River basin, the hazardous substances cadmium, lead, and zinc are the cause of the injuries described in this report. Existing concentrations of cadmium, lead, and zinc in the basin, ongoing releases of these hazardous substances from sources, and ongoing transport and exposure pathways limit natural recovery of the injured resources. There will be little recovery unless releases from sources are eliminated and transport and exposure pathways are eliminated. Existing surface water and sediment data show no evidence of either elimination of sources or pathways over the last 20 to 30 years. Therefore, it is reasonable to expect that natural recovery of the Coeur d'Alene River basin ecosystem will take hundreds of years.

Studies conducted as part of the NRDA injury assessment are identified and the final reports are provided on discs 2 and 3 of this report.

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